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# POSSIBLE AVENUES FOR COOPERATION WITH THE SOVIET UNION IN THE DEVELOPMENT OF CAPABILITIES FOR VERIFYING COMPLIANCE WITH NUCLEAR TESTING LIMITATIONS

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## MESSAGE

FROM

## THE PRESIDENT OF THE UNITED STATES

TRANSMITTING

AN UNCLASSIFIED INTERAGENCY STUDY OF POSSIBLE AVENUES OF COOPERATION BETWEEN THE UNITED STATES AND THE SOVIET UNION IN THE DEVELOPMENT OF VERIFICATION CAPABILITIES CONSISTENT WITH NATIONAL SECURITY RESTRICTIONS, PURSUANT TO PUBLIC LAW 99-145, SECTION 1003(a) (99 STAT. 705)

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*To the Congress of the United States:*

In response to the requirements of Section 1003 of the FY 1986 Department of Defense Authorization Act (P.L. 99–145), I am pleased to transmit this unclassified interagency study of possible avenues of cooperation between the United States and the Soviet Union in the development of verification capabilities consistent with national security restrictions.

The requirement under Section 1003 involves: "limited exchanges of data and scientific personnel," in general, and "joint technological effort in the area of seismic monitoring," in particular. Upon review of a number of possible scientific disciplines, it was concluded that in terms of this study, nuclear testing issues appear to offer the most promising avenues for such "scientific" cooperation and data exchange. Therefore, the attached study focuses its examination on matters relating to the verification of limitations in nuclear testing.

While the attached study focuses on nuclear testing limitations, it should be noted that in other arms control areas as well, the Administration believes that exchanges of information would, in addition to various monitoring provisions including types of on-site inspections, play an important role in establishing a verification framework.

In START ~~and~~ INF, for example, areas of possible exchange of information might include the declaration of missile and launcher facilities, the numbers of missiles and launchers at such facilities, and information on the destruction of missiles and launchers that are in excess of agreed treaty limits. In the negotiations on Mutual and Balanced Force Reductions (MBFR), we have asked for an exchange of information, to be updated annually, on the structure of forces subject to MBFR limitations. At the Stockholm Conference on Confidence- and Security-Building Measures in Europe (CDE), we believe it important to have an exchange of information both on overall force structures and on specific forces participating in military activities. In chemical weapons arms control, we believe it important, among other things, to have a preliminary bilateral exchange of data on chemical weapons stockpiles and on production facilities as a confidence-building measure prior to the entry into force of a convention banning such weapons.

The prospects for progress in arms control may be significantly enhanced if a regime of cooperation between the United States and the Soviet Union in the development of verification capabilities consistent with national security restrictions can be established. The attached interagency study describes some possible avenues of cooperation that could produce benefits in the near term in the nuclear testing limitations area.

As indicated in the attached study, the United States has long sought ~~a meeting~~ with the Soviets to present our concerns about

the verification provisions of the Threshold Test Ban Treaty (TTBT) and the Peaceful Nuclear Explosions Treaty (PNET). The United States and the Soviet Union recently agreed to have experts meet to discuss issues related to nuclear testing.

This meeting of experts, which took place in Geneva July 25–August 1, allowed the United States to present its ideas and concerns to the Soviet Union and to hear Soviet views. At the meeting, the United States presented its views of verification improvements in existing agreements, which we believe are needed and achievable at this time. A follow-on meeting of U.S. and Soviet experts is scheduled for September. We hope the Soviet Union will join in a constructive dialogue.

RONALD REAGAN.

THE WHITE HOUSE, *August 14, 1986.*

# POSSIBLE AVENUES FOR COOPERATION WITH THE SOVIET UNION IN THE DEVELOPMENT OF CAPABILITIES FOR VERIFYING COMPLIANCE WITH NUCLEAR TESTING LIMITATIONS

AN INTERAGENCY STUDY

Prepared by

U.S. Arms Control and Disarmament Agency

July 14, 1986

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# POSSIBLE AVENUES FOR COOPERATION WITH THE SOVIET UNION IN THE DEVELOPMENT OF CAPABILITIES FOR VERIFYING COMPLIANCE WITH NUCLEAR TESTING LIMITATIONS

## I. INTRODUCTION

Section 1003 of the FY 1986 Department of Defense Authorization Act (S. 1160) calls for an interagency study of "limited exchanges of data and scientific personnel" in general and "joint technological effort in the area of seismic monitoring" in particular. After reviewing a number of possible scientific disciplines, it was concluded that nuclear testing issues appear to offer the most promising avenues for scientific cooperation and data exchange. This study, therefore, focuses on matters relating to the verification of limitations in the area of nuclear testing.

## II. BACKGROUND

Effective means of verification are of critical importance to arms control. Our national security requires that we be able to assess with confidence compliance with any negotiated arms control agreements. Today, most of our major arms control agreements are monitored through what is known as national technical means of verification (NTM). While NTM has the primary benefit of being under the control of the verifying party, there are some particular applications such as for strategic and intermediate-range nuclear forces, conventional and chemical forces, and nuclear testing in which cooperative means of verification may be beneficial, or even necessary.

Cooperative means can include various on-site inspection and data exchange measures, or direct measurement schemes such as would apply to determining the yields of underground nuclear tests. On-site inspection (OSI) by observers and instruments may be able to play a role in deterring violations at agreed locations or "declared sites." The utility of OSI is largely a function of its frequency and duration, and whether, and at what costs, the activities monitored can be conducted at other times and places. Other considerations with regard to OSI include the question of how the party being monitored calculates the risk of violations being uncovered and whether they could avoid any single inspection that would detect a violation. Thus, the past record of the inspected party is a vital consideration.

Data exchanges may be beneficial to provide a benchmark for assessing compliance. If, however, the verifying party does not possess a means of independently validating the data it receives, large uncertainties could still prevail, diminishing the utility of the exchange. Nevertheless, as the amount of data exchanged is increased, the uncertainty should decrease while the difficulty of concealing illegal activities increases.

Direct measurements have the benefit of allowing the verifying party to control the means of monitoring. Direct measurement is not perfect because it is limited by the accuracy of the instruments used and, as is the case for all monitoring methods, the ability of the inspected party to manipulate the evidence. Furthermore, direct measurement will not detect violations conducted at times and places when direct measurement equipment is not engaged, and normally will not detect violations when special efforts are undertaken to conceal prohibited activities. However, even considering these limitations, direct measurement is much more definitive than any remote sensing method for determining the yields of Soviet nuclear tests.

The Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Underground Nuclear Weapons Tests (Threshold Test Ban Treaty - TTBT) prohibits U.S. and Soviet underground nuclear weapon tests with yields greater than 150 kilotons (kt). The TTBT is a Treaty signed by both Parties, but ratified by neither. Both the U.S. and the USSR have separately stated that they would abide by the yield limitation. Furthermore, since neither Party has made its intentions clear not to become a Party, both signatories are obligated by international law to refrain from acts that would defeat the object and purpose of the Treaty. At present, however, the U.S. cannot effectively verify Soviet compliance with the Treaty. Moreover, the implementation of the verification measures set forth in the Protocol to the Treaty (exchange of yield, date, time, depth, and coordinates for two nuclear weapon tests for calibration purposes from each geophysically distinct testing area and information on the geology of the testing areas), which would become effective upon ratification, will not provide this capability, since there is no way for the U.S. to independently verify the data exchanged, nor would the data, if validated, be sufficient to ensure effective verification.

Today, we monitor Soviet tests with seismic equipment located outside the USSR. In three Presidential reports to Congress on Soviet noncompliance the uncertainty in yield derived from seismic measurements, when taken into account, resulted in findings of only "likely violation", even though the seismic evidence indicates that a number of Soviet tests have central yield values above the 150 kiloton threshold. "Central yield" is defined as the yield corresponding to mean value of seismic body wave magnitudes for a particular nuclear test. While we judge that, at present, there is approximately a factor of two uncertainty in the yield estimates derived by seismic methods, there are reasons to suggest the uncertainty could be actually smaller (or conceivably larger). A factor of two uncertainty means, for example, that a Soviet test for which we derive a "central yield" value of 150 kt may have, with a 95 percent probability, a yield as high as 300 kt or as low as 75 kt.

As already mentioned, the verification provisions contained in the Protocol of the unratified TTBT would not reduce this level of uncertainty to an acceptable level. The U.S. Government has therefore continued its long-standing effort to obtain a means of monitoring that would substantially reduce our verification uncertainty. The history of the search for verifiable nuclear testing limitations will provide a backdrop for an understanding of the complicated and sometimes frustrating search for possible avenues of cooperation with the Soviet Union in the development of verification capabilities.

## III. HISTORIC PERSPECTIVE ON NUCLEAR TESTING LIMITATIONS

One of the earliest proposals for nuclear testing limitations was presented in terms of a comprehensive test ban as part of a broader disarmament proposal made by the Soviets in the U.N. Disarmament Commission in May 1955. However, there was no movement in this area for the next three years. Early in the spring of 1958, President Eisenhower suggested to Soviet Premier Khrushchev that a group of technical experts meet to determine what specific control measures would be required to ensure compliance with a nuclear test ban. After several exchanges, Khrushchev agreed and the Geneva Conference of Experts to Study the Possibility of Detecting Violations of a Possible Agreement on the Suspension of Nuclear Tests was formed. Technical discussions between experts from the USSR, Poland, Czechoslovakia, Romania, the U.K., France, Canada, and the U.S. began in July 1958.

On August 21, 1958, the Conference of Experts adopted a final report for consideration by Governments. The report recommended a world-wide system of land control posts, shipborne posts, and regular and special air-sampling flights to monitor an agreement banning nuclear weapon tests in the atmosphere, underwater, and underground. Their report was accepted as the technical basis for political negotiations by the U.S., the U.K. and the USSR, and the Geneva Conference on the Discontinuance of Nuclear Weapon Tests began on October 31, 1958. The technical basis of the international control system was provided mainly by the reports of the 1958 Conference of Experts and a 1959 technical working group of the Geneva Conference on the detection of high-altitude tests. These reports recommended a worldwide network of 160-170 land control posts, 10 shipborne posts, regular and special aircraft flights, and space satellites. The U.S. believed, however, that there was a serious risk that small underground explosions might remain undetected or be incorrectly identified as earthquakes.

The experts' report was technically limited in two respects: (1) it did not cover tests at more than 30-50 kilometers above the earth's surface, and (2) it did not have the benefit of the new seismic data obtained from the Hardtack underground

test series carried out by the U.S. after the report was submitted. The new seismic data, submitted by the American delegation in Geneva in June 1959, showed that the proposed control system would have been less effective for detecting and identifying underground tests than the experts had believed.

At the request of the State Department, the President's special assistant for Science and Technology, appointed a Panel on Seismic Improvement, headed by Dr. Lloyd Berkner, to study the new seismic data. The Berkner panel's report recommended a number of new techniques and proposed a research program to improve the capability of the verification system, described in the Geneva Conference of Experts' report, to detect and identify underground tests. The panel recommendations were the basis for much of the succeeding research in seismology, and resulted in the development of new concepts in seismic stations, instrument arrays, computational techniques, and research into the phenomenology associated with seismic waves from explosions and earthquakes.

In the political negotiations, the U.S. tried unsuccessfully to persuade the Soviet Union to enter new technical discussion on the detection of high-altitude tests and the new seismic data. The Soviets took the position that technical questions had been settled at the 1958 Conference of Experts and any needed improvements in the control system could be made by the Control Commission after the treaty came into operation.

The participants at the Geneva Conference on the Discontinuance of Nuclear Weapon Tests agreed with the principle that on-site inspection would be necessary to clarify the source of unidentified seismic events. The U.S. believed that there could be up to 100 unidentified events per year of which approximately 20 would require inspection of the site. There was disagreement between the U.S. and the Soviets on the number of on-site inspections that would be permitted. The Soviets wanted to limit each Party to two to three on-site inspections per year, when it was considered necessary. (Note: the Soviets, in effect, reserved for themselves a veto over OSI requests.) Although the issues of numbers and mandatory versus voluntary OSI were never resolved, the fact that the Soviets agreed in principle to the need for on-site inspection was widely hailed and was seen as setting a precedent for future arms control agreements. It was hoped that interim measures could be achieved that, with time, could lead to a more comprehensive agreement between the sides. The Soviets took the position that verification was less essential than reaching an agreement. The U.S. and the U.K. held that strict means of verification were required, that further study should be undertaken to assure that any agreement could be verified, and that this should be done before an agreement was signed.

On April 18, 1961, the United States and the United Kingdom submitted a complete draft treaty to the Geneva Conference.* This proposal was based on one made by President Eisenhower in February 1960. The Anglo-American Draft Treaty included a commitment to cease tests in the atmosphere, under water, at high altitudes, and underground (above seismic magnitude 4.75), and a control regime for detection and identification. Although the general characteristics of the international control system proposed in the Anglo-American draft treaty had long been accepted by both sides, the Soviet Union shifted its position on several vital verification features. For example, although the Soviets had agreed to 15 seismic stations within the USSR, they insisted that they would operate these sites. Again, even though the need for on-site inspection was recognized by the Soviets, the number of inspections proposed by the Soviets and the conditions under which they could be conducted were not satisfactory to the U.S. and the United Kingdom.

Throughout the test-ban negotiations at Geneva from October 1958 to August 30, 1961, the U.S. and the U.K. faithfully observed a voluntary suspension of nuclear weapons tests, even though there existed no means of knowing with certainty, in the absence of an effective and workable international control system, that the Soviet Union was not increasing its nuclear capability by clandestine tests. In August 1961, the Soviet Union announced that it was resuming nuclear weapons tests and did so on September 1, 1961. The United States immediately condemned the Soviet action and reaffirmed its support for an agreement to end nuclear weapons tests under effective safeguards. On September 3, President Kennedy and Prime Minister Macmillan proposed that the Soviets agree "not to conduct nuclear tests which take place in the atmosphere and produce radioactive fallout." They stated that they were willing to rely upon existing means of detection, "which they believe to be adequate," and they did not suggest any additional controls. The Soviets at first rejected this offer.

Negotiations continued in various fora until finally, in 1963, Soviet interest in a ban that did not deal with underground tests emerged, even though they had rejected the U.S./U.K. offer previously. As a result, the U.S., U.K., and the USSR agreed to the more limited goal of banning nuclear tests in all media except underground. This led to the 1963 Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space, and Under Water, usually referred to as the Limited Test Ban Treaty (LTBT).

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* See Geneva Conference on the Discontinuance of Nuclear Weapons Tests: History and Analysis of Negotiations. (Department of State publication 7258, 1961).

While discussions continued in the Eighteen Nation Committee on Disarmament, there was little further movement toward limiting underground nuclear tests until the 1974 summit meeting between the U.S. and the USSR. While the Soviets had originally called for negotiations on a comprehensive test ban, they agreed to consider a threshold treaty for underground nuclear testing. The threshold was to have been in terms of yield or possibly seismic wave magnitude. The U.S. initially proposed limiting tests to a certain value in body wave magnitude, but because body wave magnitude for a particular value of yield varies with test site location, the focus of the discussions was changed to yields. While this resolved the problem of the variability of body wave magnitude measurements, it introduced the problems associated with the accuracy of seismic techniques for the determination of yield. The TTBT was signed by the U.S. and the USSR in July 1974.

The TTBT and its associated Protocol contain provisions for the exchange of geophysical data and announcing the yields of two explosions for calibration purposes in each geophysically distinct area (provisions which have not been implemented because the Treaty has not been ratified). However, the Treaty provides no mechanism by which one Party could independently validate the accuracy of the data provided by the other Party. Seismic techniques are inadequate to verify effectively the yields of Soviet tests. Prior to the signing of the TTBT, U.S. policy, as well as seismic research, had concentrated on a comprehensive test ban. Seismic research had been aimed at the problems of detecting and identifying low yield nuclear tests with relatively less emphasis on determining yield.

While progress has been made in understanding the natural processes that affect yield estimation based on remote seismic measurement, the uncertainties in the yield estimation process cannot be sufficiently reduced without direct measurement of yields at the Soviet test sites. The Soviets, and some critics of existing U.S. policy in this country, have asserted that adequate verification will result from the exchange of data called for in the Treaty. However, these data will be of limited value for verification purposes unless they can be independently verified by the U.S. Even if the data were accurate and could be verified, they would not be sufficient to effectively verify Soviet compliance with the 150 kt threshold of the TTBT, because the limited data to be exchanged would not reduce the uncertainty in the seismic yield estimation process to acceptable levels.

The question of Peaceful Nuclear Explosions (PNEs) was also addressed during 1971-1974 and continued until the Treaty on the Limitation of Underground Nuclear Explosions for Peaceful Purposes, usually referred to as the Peaceful Nuclear Explosions Treaty (PNET), was signed in 1976. Since each

individual nuclear explosion could not be greater than 150 kt, additional monitoring measures had to be negotiated for explosions conducted at locations other than at the designated weapons test sites and for salvos of explosions whose aggregate yield exceeded 150 kt. Provisions were included for on-site measurements of each explosion by downhole instrumentation, similar in result to the current CORRTEX equipment,if the aggregate yield was planned to exceed 150 kt. Seismic instruments were also to be allowed in the test area if the aggregate yield was planned to exceed 500 kt. It is worth noting that even if the PNE Treaty were in force, the on-site measures would not have been implemented up to now because the Soviets apparently have not planned group explosions over any particular Treaty specified threshold which would trigger OSI or installation of U.S. devices on Soviet territory.

Technical discussions on nuclear testing issues, principally related to a Comprehensive Test Ban (CTB), have been held with the Soviets in the multilateral arena in Geneva. The U.S. presented papers at the Conference of the Committee on Disarmament (CCD) at least as far back as 1971 and again in 1973 and 1976. These papers discussed capabilities for discriminating between explosions and earthquakes, data from arrays of seismometers and networks of such stations and various other seismology topics. There was, however, not much expert discussion of these U.S. contributions until the Ad-Hoc Group of Scientific Experts (GSE) was formed in 1976.

One of the tasks of the GSE was to describe a network of seismic stations that would provide data to the members for use in monitoring a CTB. Initially the Swedes, among others, attempted to establish a deliberative body within the CCD to conduct verification analyses. The U.S. did not want to rely on such a multinational group for verification decisions. As an alternative, the CCD, on the recommendation of the U.S., formulated a plan for the exchange of seismic data and for conducting studies relating to that data. The GSE selected an optimum network of seismic stations from CCD member states and evaluated its capability to provide data adequate for verification. An elaborate set of data parameters was agreed upon for reporting in a bulletin format. The World Meteorological Organization telegraph system was adopted for the exchange of these data bulletins. The exchange of complete seismograms, using digital techniques and satellite transmission, has been explored. Studies and experiments on these transmission techniques continue at the present time. It is significant, however, that throughout this period in which testing limitations have been of such concern, at no time have there been any joint projects of bilateral exchanges of data except for some limited discussions during the actual trilateral CTB negotiations.

In the summer of 1977, about one year after the conclusion of the PNE phase of the threshold treaty, the U.S., the U.K. and the USSR began negotiations toward a comprehensive test ban. Initially, the U.S. and the USSR had different views concerning the proposed duration of the treaty--the U.S. wanted a treaty of unlimited duration while the USSR wanted a three year treaty that would continue depending on the actions of others, specifically France and China. By the summer of 1978, the U.S. revised its position and proposed a CTB of only three years duration.

Initially, the questions of seismic stations (numbers, kinds, and locations) were fairly open on both sides. As the negotiations on the number of seismic stations proceeded, the Soviets hardened their position on in-country seismic stations--demanding that they had to be nationally manned. The Soviets constantly raised their concern about unmanned stations or "black boxes." The U.S. eventually proposed ten seismic stations in the Soviet Union in conjunction with a three year treaty. The USSR said they would accept ten stations in the USSR provided that there would be ten stations in the U.S. and ten stations in the U.K. and its territories. This created a serious impasse. The U.S. and the U.K. felt that one station in the limited territory of the U.K. would be sufficient, but the Soviets would not budge. They took the position that equal participation required equal responsibilities. They further indicated that if 10-10-10 was not satisfactory, any other set of equal numbers would be acceptable. While the Soviets had apparently agreed in concept to both on-site inspection and in-country seismic stations, these issues were still unresolved when the negotiations were suspended in November 1980.

The U.S. has not resumed the trilateral CTB talks since they recessed in November 1980 because under present circumstances a CTB would be against the security interests of the United States and its allies and would not be effectively verifiable. In the existing environment, the security of the United States and our Allies depends on a credible U.S. nuclear deterrent. In such a situation, where we must rely upon nuclear weapons to deter aggression, nuclear testing will be required. A comprehensive test ban remains a long-term objective of the United States arms control policy, but such a ban must be viewed in the context of a time when we do not need to depend upon nuclear deterrence to ensure international security and stability, and when we have achieved deep, broad, and verifiable arms reductions, improved verification capabilities, expanded confidence-building measures, and a greater balance in conventional forces.

The verification of a comprehensive test ban, and especially any testing moratorium such as proposed by the Soviet Union, remains a major problem. In the context of the verification

procedures discussed (but not agreed) in the CTB trilateral negotiations, there would still be significant uncertainty about our ability to verify Soviet compliance, that is to detect and identify with sufficient certainty a potentially significant level of clandestine testing. Our concerns are heightened by likely Soviet violations of the TTBT and by Soviet violation of the Limited Test Ban Treaty, the LTBT.

IV. OPPORTUNITY FOR COOPERATIVE MEASURES

There are two distinct problem areas that can be addressed jointly by the U.S. and the USSR. The first deals with sufficiently accurate yield measurements that would allow effective verification of yield thresholds such as the 150 kt limit of the TTBT. Solution of this problem area would provide the basis for moving forward on ratification of the TTBT and the PNET. The second deals with the ability to detect and identify low yield nuclear tests. This requires solution of the problem of detecting and identifying low yield tests not only underground but also underwater, in the atmosphere, and in outer space. Programmed capabilities will greatly enhance our ability to detect and identify low yield nuclear tests within the atmosphere, although there may remain some uncertainty regarding the country conducting such tests if they are conducted over remote areas. With these technological advances in hand and at a time when we do not need to depend upon nuclear deterrence to ensure international security and stability, and when we have achieved deep, broad, and verifiable arms reductions, expanded confidence-building measures, and a greater balance in conventional forces the conditions would exist for proceeding towards a treaty that would ban low yield nuclear tests.

a. Verification of Yield Thresholds

As noted above, the provisions of the TTBT provide no mechanism for reducing the level of uncertainty of yield estimation to an acceptable level. (We believe that no method of yield estimation based only on information derived solely from seismic measurements or seismic theory can reduce the uncertainty to an acceptable level.) Uncertainties in the yield estimation process cannot be sufficiently reduced without directly measuring the yield of Soviet tests with instruments which are fundamentally much more accurate than seismic methods.

The President has stated that he is prepared to move forward on ratification of the TTBT and PNET if the Soviets would agree to the use of an effective verification system incorporating CORRTEX (Continuous Reflectrometry for Radius versus Time Experiment) method.

The most productive joint Soviet-U.S. discussions of monitoring measures would be those which would involve the technology and implementation procedures for direct yield measurement. The United States believes that it has identified in CORRTEX a measurement technique which will reduce the uncertainty in yield measurement to an acceptable level and will do so without danger of compromising other sensitive information about the nature or performance of the nuclear device whose yield is to be measured.

CORRTEX is a hydrodynamic yield measurement technique that measures the rate of propagation of the underground shock wave from an explosion. This technique uses an electric coaxial cable located in the device emplacement hole or in a nearby, parallel "satellite" hole. When the nuclear device is detonated, a shock wave propagates through the ground, crushing and shortening the cable. The rate by which the cable length changes is recorded by measuring the changing transit times of low energy electrical pulses sent down to, and reflected from the cable end. This rate is a measure of the propagation velocity of the explosive shock wave through the ground which is, in turn, a measure of the yield of the nuclear explosion.

The electronic device that provides the timing signals is a battery-powered, suit-case sized unit that may be remotely controlled. All equipment for power, recording, and data reduction can be contained in a small trailer.

CORRTEX has been shown to be accurate to within 15 percent (with 95 percent confidence) of more direct, radiochemical yield measurements for tests with yields greater than 50 kt. This is based on its use at the Nevada Test Site in over 100 tests with the sensing cable in the device emplacement hole and four tests with the sensing cable in a satellite hole. The accuracy of the technique is believed to be relatively independent of the geologic medium provided the satellite hole measurements are made in the "strong shock" region near the nuclear explosion. At greater separation distances, the medium becomes more important. A satellite hole separation distance of 14 meters (46 feet) is appropriate for a test near 150 kt.

CORRTEX is expected to be initially accurate to within 30 percent (with 95 percent confidence) of the actual yield at Soviet test sites for tests above 50 kt. An accuracy of 30 percent of the actual yield means, for example, that a test that produces CORRTEX measurements estimated to be associated with a "central value" yield of 150 kt, could, with a 95 percent probability, have a yield as high as 195 kt (150 kt plus 30 percent of 150 kt) or as low as 105 kt (150 kt minus 30 percent of 150 kt).

The Soviets were exposed to technology similar to CORRTEX during the PNET discussions. At that time, they indicated that they possessed similar technology. Therefore, a technical basis has already been established for the necessary discussions. The U.S. is prepared, as evidenced by the President's March 1986 offer, to demonstrate to Soviet technical experts how we would emplace CORRTEX instruments, how measurements are recorded, and how the data are analyzed. In any cooperative technical effort, the Soviet experts would have the opportunity to examine the CORRTEX data from a Soviet nuclear test in order to determine for themselves that no sensitive information, not relevant to TTBT verification, has been compromised. For their part, the Soviets would be permitted to bring any equipment they deemed necessary to measure the yield of the test.

Successful implementation of a direct yield measurement regime for verification of the TTBT and the PNET will establish the principle of on-site inspection at declared facilities--in this case the site of nuclear tests. Joint Soviet-U.S. discussions to establish direct yield measurements will necessarily require negotiation of all the logistical aspects of such on-site presence, including the size and composition of the technical teams who would make measurements, agreement on the quantity of equipment which can be brought into the country, identification of allowed instrumentation, inspection of equipment by the party whose test is to be measured, establishment of housing, feeding, and transportation arrangements for the team making measurements, and procedures for sharing and transferring data from the country in which the test is to be performed.

Though not exhaustive, the above issues that would require negotiation are indicative of the long list of issues which must be addressed in making the transition from an agreement in principle to on-site inspection implementation. Any one of these elements, if not properly resolved, could frustrate the ultimate objective of the inspection regime. While not as glamorous as some aspects of arms control, the negotiation of such technical and logistical details is critical and may be extremely time-consuming. Therefore, early joint Soviet-U.S. discussion of these issues can have a major impact on timely ratification of the TTBT and PNET.

b. Detection and Identification of Low Yield Nuclear Tests

The second problem area, detection and identification of low yield nuclear tests is even more difficult because the solution requires effective monitoring in all environments--underground, underwater, in the atmosphere, and in outer space. Consequently, verification of any limitation of low yield nuclear tests would require, at a minimum, the utilization of several techniques.

For example, detection and identification of low yield nuclear tests will necessitate installation of an in-country seismic network and the implementation of on-site inspections. In addition, regional seismology (operating distances up to 2000 kilometers from the source) will be a critical technology for the detection of underground tests. Measurement techniques for the collection and detection of atmospheric nuclear explosion debris will still require some refinement when working at or near levels of naturally occurring background radiation. Further development of hydroacoustic techniques could contribute to detection of small nuclear tests in remote ocean areas.

Recognizing the full scope of the problem of detecting and identifying low yield nuclear tests in all environments, which must be solved, this paper will address only one part of the problem--monitoring low yield underground nuclear tests--because this is the area where the U.S. believes that cooperation with the USSR would be the most productive.

The requirements for in-country monitoring stations have been discussed with the Soviets in many fora since the late 1950s (see the Historical Perspective section). There remain several areas in which seismic monitoring can be profitably addressed by Soviet and U.S. technical experts. Further work may strengthen the basis for seismic detection and identification of low yield nuclear tests in advance of the achievement of the other criteria which must be met before the United States could consider a comprehensive test ban to be in its national interest.

It is assumed that whatever the level of detection of seismic events, there will be some events detected whose origin (e.g., nuclear test, earthquake, chemical explosion) will be uncertain -- unidentified (i.e., unresolved as to their origin) events. While improvements in seismic monitoring devices could be expected to provide additional data that could identify some of the events that cannot be identified at current sensitivity levels, the net effect of improvements in sensitivity will be to increase the number of unidentified events.

On-site inspection, as a concept, is also used to describe inspections conducted to remove ambiguity when information from other sources indicate that a potential violation of a treaty in force may have already occurred. However, on-site inspection will only be useful when the precise location of the ambiguous event can be determined. On-site inspection could contribute to identification of the source of surface or near surface explosions, where surface disturbances would clearly indicate the location. For small underground explosions, it would be nearly impossible to locate the source with sufficient precision to permit the verifying party to drill into the cavity created by the test to sample the explosion debris.

The basic elements which could be addressed in joint discussions include the fundamental science of the transmission of seismic waves within the Soviet Union; the types of equipment which would need to be permanently installed for the measurement of seismic data; the equipment which would need to be installed for the recording and transmission of seismic data to national data analysis centers; and the numerical data processing techniques which would be used for identifying the source of a seismic event based on the characteristics of the seismic data. These issues are described in more detail below:

- Seismic Wave Transmission: The U.S. is actively pursuing the seismic research which would be critical to the detection and identification of low yield (below 10 kt) nuclear tests. Of particular significance is research on high frequency seismic waves. Instruments capable of detecting high frequency seismic waves have been developed and an experimental seismic array containing such equipment is in operation. To be confident that high frequency seismic waves can be useful for detection and identification of low yield nuclear tests, two issues need further study: the availability of sufficiently quiet, low background seismic noise sites within the Soviet Union at which seismic stations could be located, and knowledge of the transmission characteristics of high frequency seismic waves within the Soviet Union. The degree to which seismic wave energy is absorbed and scattered as a seismic wave travels away from a nuclear explosion in the U.S. has been studied extensively and much of this work has been published in the scientific literature. Similar information is not available for explosions within the Soviet Union. A joint U.S.-Soviet effort could seek to determine the degree to which high frequency seismic wave energy is absorbed and scattered in the Soviet Union. Such an effort would establish a more realistic basis for the utility of high frequency seismic waves for detection and identification of low yield nuclear tests. While data obtained from outside the Soviet Union are useful, Soviet-U.S. cooperation in obtaining and evaluating data from within the Soviet Union is essential.

- Seismic Equipment and Data Handling: During the trilateral CTB negotiations of 1977-80, the United States described to the Soviet Union tamper-proof, remotely operated seismic stations which would record and transmit seismic data for analysis in the United States. The U.S. has continued research on such stations. Modification in these stations would be required to provide the capability to record and transmit data on high-frequency seismic waves. Joint Soviet-U.S. efforts could resume on the criteria for the location and operation of such stations to include characterization of the sites which would have to be available to ensure accurate instrument operation. Such an

effort would have to include data gathering from potential sites for remote stations in the Soviet Union and should include installation of research instruments to validate that such instruments can operate reliably, to include data transmission, throughout the broad range of environmental conditions within the Soviet Union.

- Seismic Wave Analysis: The effectiveness of any low yield underground nuclear test verification regime based upon the analysis of seismic waves will ultimately depend on the ability to identify a nuclear explosion by distinguishing between nuclear explosions and other sources of seismic energy, e.g., chemical explosions and earthquakes. The object must be to minimize the number of recorded seismic events whose source is ambiguous. A joint Soviet-U.S. effort could seek to identify analytic techniques which would positively identify the origin of recorded seismic signals. Such a joint study cannot be done in the abstract, but should be tested against real data which would be typical of that which would be recorded by instruments located at the prospective location of seismic stations. No analytic technique can hope to eliminate all ambiguous events but it would be very helpful if the two sides could agree on which technique can be the most effective.

## V. CURRENT STATUS

We have sought on a number of occasions in the past several years to engage the USSR in discussions on verification improvements in the nuclear testing area, but thus far without success. In 1983, the U.S. Government sought on three separate occasions to engage the Soviet Union in a discussion of essential verification improvements for the TTBT and the PNET. In September 1984, the President proposed in his address to the United Nations General Assembly that the United States and the Soviet Union find a way for Soviet experts to come to the U.S. nuclear test site and for U.S. experts to go to theirs to measure directly the yields of nuclear weapons tests. In July 1985, the President expanded his offer with an unconditional invitation for Soviet experts to go to the United States nuclear test site to measure the yield of a U.S. nuclear test with any instrumentation devices they deemed necessary. There was no requirement for a reciprocal visit by U.S. experts to a Soviet test site. In December 1985, President Reagan proposed to General Secretary Gorbachev that U.S. and Soviet experts on nuclear testing limitations meet in February 1986 to discuss our respective verification approaches, and to address initial tangible steps to resolve this issue.

Most recently, on March 15, 1986, the President urged the Soviet Union to join the U.S. in discussion on finding ways to

reach agreement on essential verification improvement of the TTBT and PNET. In this respect he provided details to the Soviet Union on the U.S. CORRTEX hydrodynamic measurement system and proposed that General Secretary Gorbachev send Soviet scientists to our Nevada Test Site during the third week of April 1986 to fully examine CORRTEX. At that time, the Soviets could also monitor a U.S. nuclear test. Finally, the President indicated that, if the Soviet Union will join us in an agreement for effective verification, including the use of CORRTEX, the U.S. would be prepared to move forward on ratification of the TTBT.

The Soviets have stated that they have developed and have available a system that is used to obtain data similar to that obtained by CORRTEX. Aside from this assertion, the Soviet Union has not responded to any of the above U.S. initiatives, which were aimed at constructively addressing our mutual concerns.

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